②

PROFESSIONAL PAPER 425 / January 1985

AD-A153 740

COSTS AND BENEFITS OF TRAINING AND EXPERIENCE

Stanley A. Horowitz
Bruce N. Angier

N00014-[illegible]-C-0725

CNA
CENTER FOR NAVAL ANALYSES

PROFESSIONAL PAPER 425 / January 1985

COSTS AND BENEFITS OF TRAINING AND EXPERIENCE

Stanley A. Horowitz
Bruce N. Angier

Naval Planning and Management Division
CENTER FOR NAVAL ANALYSES
2000 North Beauregard Street, Alexandria, Virginia 22311

ABSTRACT

On-the-job training continues throughout the careers of enlisted men in the U.S. Navy. This kind of experience-induced training entails no formal training cost, but it requires payment of the higher wages and benefits due more senior individuals. This paper examines where the balance is between the costs and benefits of such training. Benefits are estimated in four contexts, three of which use measures of personnel performance based on equipment readiness. The fourth is based on supervisor evaluations. Costs are addressed in two ways: billet based and individual based. The analysis strongly demonstrates the contribution of experience-induced training and indicates that it is well worth the cost.

COSTS AND BENEFITS OF TRAINING AND EXPERIENCE

1. INTRODUCTION

Training in the military--as in most lines of work--is a never ending process. Training can be considered to include everything that improves an individual's ability to do his job without changing the environment in which it is performed. It takes many forms, starting with basic military training and formal entry-level skill training through more advanced formal schooling to the acclimatization of early on-the-job training. It does not stop there. As an enlisted person continues through his career, he accumulates experiences that include a substantial component of training. As someone continues in a job, he usually learns to do it better.[1] The purpose of this paper is to determine whether experience-induced training is a good buy in the United States Navy. In other words, would national defense be better served by the procurement of a more experienced force?

Answering this question requires quantification of the benefits accruing to the Navy as a result of experience-induced training and an evaluation of whether they are worth the attendant costs. It also requires proper measurement and allocation of the cost of formal training. While each member of a more experienced force will tend to have more formal training, a more experienced force means less need to supply training to new enlistees--since when individuals stay longer, replacements have to be trained less frequently.

We will present evidence from four sources on the extent to which experience produces effective training. The evidence consists of statistically derived relationships between experience and performance. Of course it is not easy to measure the performance of naval personnel. One thing we can say, though, is that better trained maintenance personnel should provide equipment that works more often. This analysis, therefore, is largely limited to enlisted maintenance personnel and their output.

For the most part we will use equipment readiness as a measure of the output of the training process. Since the focus is on experience-induced training, our main approach will be to relate aggregate measures of equipment readiness to the experience mix of the personnel who produce that level of readiness.

---

[1] Experience may not always improve performance. Without proper supervision, an individual may only become more confident about doing the wrong thing. But the results presented here make one think that such instances are rare.

Initially we will judge the cost-effectiveness of experience-induced training using a relatively simple, billet-based methodology for costing people with different levels of experience. Later, a replacement cost approach will be introduced to examine tradeoffs between accession and retention. We hope to convince you that buying experience is a good way to buy training. Let us turn to the first source of evidence.

2. RECENT TRENDS IN SHIP READINESS

We at the Center for Naval Analyses (CNA) have gathered quarterly data on the fraction of surface combatant ships with no serious mission degrading equipment failures between 1977 and 198?. This proportion fell to a trough in 1981, and then rose to a new high. During the latter part of this period the Navy's shortage of experienced petty officers in maintenance occupations decreased sharply. In as-yet unpublished work, Alan J. Marcus analyzed the temporal variation in ship material readiness as a function of the availability of both experienced and inexperienced personnel to perform maintenance aboard suface combatants. The equation he estimated is as follows:

$$SCR = -61.0 + \underset{(1.14)}{30.0f_j} + \underset{(2.79)}{79.0f_s} - \underset{(.26)}{.04t} \quad (1)$$

$R^2 = .32$

Number of observations = 26

t-values are in parentheses,

where

SCR = the percent of ships substantially combat ready--that is, with no serious mission-degrading equipment failures

f_j = ratio of number of E-1 to E-4 personnel in maintenance occupations on surface combatants to number of billets authorized for such people

f_s = ratio of number of E-5 to E-9 personnel in maintenance occupations on surface combatants to number of billets authorized for such people

t = time; first quarter of 1977 equals 1, second quarter equals 2, etc.

Changes in the "fill rate" for senior personnel (f_s) are statistically significant and much more important than changes in the

fill rate for junior personnel. When the manning variables are included, the time trend has virtually no relationship to fleet readiness.

Since junior personnel (below E-5) make up 53 percent of the authorizations for shipboard enlisted maintenance people, equation (1) implies that an additional senior enlisted maintainer contributes three times as much to ship readiness as a junior one. This is a provocative, but not yet conclusive result. It does not prove causality. It is based solely on a coincidence between readiness and manning during one particular time period. Perhaps both factors were being driven by an omitted third factor--like morale in the military.

To avoid this kind of ambiguity about cause and effect, we can examine variations in performance across units (ships or aircraft squadrons) rather than over time. It is to such analyses we now turn.

3. VARIATION AMONG SHIPS

We drew on a study of the performance of maintenance personnel aboard surface combatants [1]. It looked at the readiness of 91 ships over a 3-year period. The measure of ship readiness was the amount of mission-degrading downtime suffered by the equipment maintained by men in each of six occupations, or ratings. Such downtime is routinely reported on casualty reports, or CASREPs. These CASREPs were the source of performance data. The occupations studied were boiler technician (BT), machinist's mate (MM), gunner's mate (GM), fire control technician (FT), torpedoman's mate (TM), and sonar technician (ST).

We developed aggregate statistics describing the characteristics of the enlisted personnel in each crew by occupation. The characteristics examined for our designated occupations were education, test scores, training, length of service, paygrade, turnover, race, and marital status. We also controlled for crew size. The characteristics of individuals were weighted by the fraction of the observation period they were assigned to a particular ship.

Manning, of course, is not the only factor that affects material condition. The amount of time that equipment fails to function can also be expected to depend on the age of the ship, the length of time since it was last overhauled, and differences in the kind of equipment, among other things. We included these nonpersonnel factors in our analysis to hold them constant.

Table 1 summarizes our results regarding the determinants of the readiness of shipboard equipment maintained by men in each of the six ratings. The ratings are listed across the top, and the determinants of readiness down the side. A check means that we found a relationship, and that its direction was not unexpected. An X indicates an unexpected result; there was one such case. Blanks mean that no important relationship was found. The results are largely as expected, though they differ by occupation.

TABLE 1

DETERMINANTS OF PERSONNEL PRODUCTIVITY AND EQUIPMENT READINESS
AS MEASURED BY CASREP DOWNTIME

Determinants of readiness	Equipment maintained by: BT	MM	GM	FT	TM	ST
Experience-related personnel characteristics						
1. Paygrade	✓	✓	✓	✓	✓	✓
2. Length of service	✓	✓	✓	✓	X	
3. Prior sea experience		✓	✓			✓
4. Quantity of formal Navy training	✓	✓	✓		✓	✓
Other personnel characteristics						
5. Crew size	✓	✓		✓	✓	
6. High-school graduation				✓		✓
7. Entry test scores	✓		✓	✓		
8. Turnover		✓				
9. Marital status	✓					✓
10. Race				✓		
Ship and equipment characteristics						
11. Ship age	✓	✓			✓	
12. Time between overhauls			✓	✓	✓	
13. Equipment complexity	✓	✓	✓	✓	✓	✓

The payoff to experience is reflected in the first three lines of the table.[1] Experience is the most consistent predictor of readiness. It enters in some way for every rating. Almost all these effects are statistically significant, and only one is unexpected (length of service for TMs). For them, longer service, holding paygrade constant, seemed to hurt readiness. But if paygrade is allowed to vary with length of service, as it actually does, this apparent anomaly is erased. It appears that experience-induced training exists and consistently contributes to the output of military units. The fleetwide results cited do not seem to be just an accident of timing.

4. VARIATION AMONG AIRCRAFT SQUADRONS

A similar unit-level analysis has been performed for naval aviation [2]. The work examines the performance of A-7 squadrons aboard aircraft carriers. Observations were obtained for 292 squadron-quarters of operations between 1977 and 1980.

Squadron performance was measured principally by the number of flights (or sorties) by A-7s off the carrier in a quarter. The effect on the squadron's sortie rate of changing the experience level of enlisted maintenance personnel was estimated. Since we had no strong beliefs about how different levels of experience substitute for each other, a flexible production function was desired. The generalized Leontief production function suggested by Diewert was chosen [3]:

$$Q = \sum_{i=1}^{n} a_{ii} X_i + \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{j=1}^{n} a_{ij} X_i^{1/2} X_j^{1/2}$$

where Q = output and the X_i are inputs.

Experience was characterized by both years of service and paygrade. The latter formulation gave slightly better results, which are summarized in table 2. Note that, on the margin, an additional junior person actually seems to harm squadron performance, presumably by requiring the attention of more senior people. In general, people in the two more senior groups were found to enhance the performance of the junior group. The most senior group, which is relatively small, had by far the largest impact on the sortie rate. This effect was statistically significant.

---

[1] Line 4 was included in the category of experience-related characteristics because more experienced people will tend to have attended more Navy schools. The important point here is that lines 1-3 do not capture the payoff to formal training, since that factor is held constant in the regression analysis.

TABLE 2

MARGINAL PRODUCT OF PAYGRADE GROUPS IN GENERATING SORTIES
(Sorties per quarter)

E-1 - E-4	E-5 - E-6	E-7 - E-9
-0.5	6.2	29.1

5. PERSONNEL COSTS IN UNIT-LEVEL STUDIES

The above analyses yield measures of the relative value of enlisted maintenance personnel with different levels of general experience and particular training. The next question to be addressed is how to develop appropriate estimates of the cost of acquiring, training and compensating personnel in these units. Such estimates would allow calculation of how unit costs might change as the experience mix of unit personnel changes.

One way to develop the costs of an individual employee is to attribute those costs to his position. In military terminology, this position is often called a billet. It is normally described by occupation (rating, Military Occupational Speciality (MOS)), and paygrade (rank, rate).

The billet costing method is restrictive in that it does not consider different ways of getting persons to a given level of paygrade or experience. All other policies for accession, training, compensation, and retention policies are assumed constant, so their costs may simply be accumulated. The method also assumes that the policy changes suggested are small enough that they do not result in infeasible steady-state force structures (for example, more individuals with 10 years experience than with one year's experience in an organization with no lateral entry).

Even with the above restrictions, there are many ways these costs can be treated. The one that we feel is most valuable for making resource allocation decisions is to try to make billet costs measure the marginal or incremental cost of manning an organization. These kinds of cost estimates are more useful than average or budget cost because they are a monetary measure of the resources that can be reallocated to other activities by buying fewer billets, and a measure of the additional resources that must be earmarked to buy more billets. Information of this nature is extremely important in addressing questions such as the life-cycle cost of weapon systems or delivery platforms that require additional personnel, and hence the merits of different systems and platforms. If comparable cost estimates for civilian personnel are available, billet-cost estimates are valuable in determining whether the substitution of civilian for military personnel is cost effective. In

this paper we are concerned with the cost of substituting senior billets for a larger number of junior ones, a conceptually similar exercise.

The Navy has recently developed improved models for collecting, accumulating, and displaying billet costs [4]. These models include costs for enlisted personnel, officers, and civilians. A table from [4] displaying costs for enlisted billets is reproduced here as table 3. The first seven cost elements include different pay and allowance categories. Cost elements eight and nine are the result of efforts to apportion the costs incurred when people leave the Navy. Elements ten through twelve amortize the investment in recruiting and providing formal training to personnel. Element 13 is a miscellaneous category for costs that did not easily fit in other categories.[1] The result of these calculations is the Navy Enlisted Billet Cost. This is the annualized cost allocated to each billet.

[1] This is not the final word on these estimates. Questions have been raised about the amortization schemes for training costs, and the new directives on accrual of retirement funds may also necessitate changes. However, the basic framework is in place.

TABLE 3
NAVY ENLISTED BILLET COST MODEL
(FY 1983 Data)

Cost elements	Costs by grade (FY 1983 dollars)						
	E-3	E-4	E-5	E-6	E-7	E-8	E-9
1. Basic pay	8,867	10,083	12,015	15,023	18,321	21,818	26,403
2. Selective reenlistment bonus	0	708	704	509	168	9	6
3. Proficiency pay	0	2	55	107	140	153	133
4. Hazard pay	50	97	231	262	362	468	463
5. Sea pay	1	437	585	739	928	772	630
6. Variable housing allowance	323	414	642	920	1,137	1,261	1,412
7. Allowances	2,364	2,932	4,011	5,106	5,694	6,068	6,485
8. Separation	339	684	601	281	419	781	1,095
9. Retirement	286	387	625	1,028	1,251	1,357	1,400
10. Accession	1,429	1,320	1,042	356	212	199	177
11. Initial training	120	1,583	1,777	1,101	618	227	50
12. Advanced training	0	862	1,080	1,026	760	639	388
13. Undistributed costs	1,237	1,441	1,810	2,229	2,341	2,370	2,393
Navy Enlisted Billet Cost	15,016	21,049	25,179	28,687	32,351	36,121	41,032

6. CONCLUSIONS FROM AGGREGATE ANALYSES

Now we have estimates of both how much more productive people with more experience-induced training are and how much they cost. Thus, we can begin to assess whether experience-induced training is a good buy.

Returning first to the fleetwide time-series analysis of surface ships, recall that an additional individual in one of the top five paygrades was estimated to be three times as productive as a more junior person on average. Weighting the billet costs for the maintenance ratings studied by the distribution of billets, we estimate that a senior person costs approximately 150 percent as much as a junior person. Thus, a given expenditure on senior people can be expected to yield twice as much output than the same expenditure on junior people.

Of course, that does not mean that we should only have senior people. Beyond some point there would not have been enough skilled work for all of them to do, and they would have to do other work in which some of their training is no particular advantage. We cannot identify this point because of the linear nature of the analysis. The linear form seemed to describe the data well, but it shouldn't be extrapolated too far.

The analysis of A-7 squadrons used a more flexible functional form that captures the decreasing possibilities for substitution as the proportion of senior people increases. The estimated production function was combined with billet costs to determine alternative ways of achieving the same sortie rate. The results of this procedure are shown in table 4.

TABLE 4

CURRENT AND LEAST-COST FORCE BY PAYGRADE
FOR 12-PLANE A-7 SQUADRONS

	Number of enlisted maintenance personnel per squadron				Annual cost (thousands of FY 83 dollars)
	E1-E4	E5-E6	E7-E9	Total	
Current	129	65	12	206	4,304
Least cost	86	60	23	169	3,796
Difference	-43	-5	+11	-37	508

It appears that moving to a force with more senior people--the ones with the most experienced-induced training--and fewer junior people could maintain squadron performance with 18 percent less manpower at a life-cycle cost savings of 12 percent.

7. EVIDENCE FROM INDIVIDUAL PERFORMANCE

The analyses discussed so far have two shortcomings. First, they only address the level of training of maintenance personnel. Operators and support people are ignored. Second, the use of billet costs does not capture some of the most important aspects of emphasizing experience-induced training. Fostering higher experience levels, for example, would reduce the frequency with which replacements must be trained. In effect, the amortization period for formal training costs would be lengthened, reducing annualized costs. On the other hand, higher experience levels would require higher retention and the attendant costs. Harking back to the A-7 analysis, doubling the number of people in paygrades E-7 to E-9 would require higher compensation for experienced personnel and thus would increase total costs. Would experience-induced training still be a good buy? Another study CNA performed sheds some light on this question.

This analysis, by Ellen Balis, was concerned with changing both the experience mix and the level of reenlistment bonuses in order to maximize the output of that portion of the enlisted force with less than 8 years of service [5]. The issue is balancing cost and effectiveness.

A replacement-cost approach was taken. Replacement costs are developed to answer the question "What is (the present value of) the cost of developing one representative individual with a particular set of skills and a particular level of experience?" For this work, three kinds of personnel costs are involved: (1) the cost to get a recruit to the reenlistment decision, which includes recruiting, induction processing, recruit and initial skill training, and 4 years of regular military compensation; (2) the cost of first-term selected reenlistment bonuses for 4-year reenlistments, and (3) the cost of second termers, which is regular military compensation for years 5 through 8. Earlier CNA work was drawn on to calculate recruiting costs [6].

Also important in the determination of a replacement cost is the continuation behavior of individuals during and between terms of service. For example, if under current policies four new enlistees must be obtained to have one individual survive to the second term of service, and if the cost of Recruit Training is $2,500 per enlistee, then $10,000 must be spent on recruit training for each second-term survivor. This method also allows replacement costs to vary to the extent that reenlistment rates are a function of compensation (see [7] for recent Navy estimates of this factor).

The effectiveness of first termers is estimated from the Enlisted Utilization Survey of Navy supervisors. This work is described in more detail in a paper by A. Quester and A.J. Marcus [8]. The survey asked supervisors to rate the productivity of individuals relative to that of

the average 4-year specialist.[1] For second termers, productivity after 4 years is assumed to remain constant--surely an underestimate of the value of experience-induced training.

Cost and effectiveness data were developed for eight groups covering 20 Navy occupations, both technical and nontechnical. For each group, optimal levels of both accessions and reenlistment bonuses were derived for different assumptions about reenlistment decisions and recruiting costs. Table 5 shows the results of this derivation under one of the most conservative sets of assumptions.[2] The optimal reenlistment bonuses are expressed in terms of how much second-term pay would increase as a result.

TABLE 5

IMPLICATIONS FOR ACCESSIONS AND BONUS LEVELS

Occupational area	Cohort size: Current	Cohort size: Optimal	Second term pay increase (%)
Health Care	2,503	2,117	28
Logistics	3,609	2,873	33
Aviation Mechanical	1,691	1,398	36
Marine Engineering	2,190	2,058	10
Radioman	550	384	40
Mechanical	4,553	3,766	28
Aviation Electronics	2,825	1,936	46
Electronics	1,763	1,484	35
Total	19,684	16,706	29

[1] This is a totally subjective measure of productivity. Every supervisor was free to determine it in his own way.

[2] Indeed, the optimal bonus levels shown here are below any shown in [5] because we used a zero discount rate.

The results mean that increasing the number of second termers relative to first termers is cost effective. The total number of people serving in the first two terms, however, decreases with optimal policies, because the increase in second termers is more than offset by the decrease in first termers that can accompany it without a loss in effectiveness. Accession levels could be cut 15 percent among these groups. This reduced demand is of some interest in an era of fewer potential recruits. The resultant cost savings for these groups average 4 percent, assuming no change in first-term pay.

The full potential savings are larger if cuts in first-term pay are allowed. If the Navy took in 15 percent fewer people each year, it could maintain the quality of its incoming people without paying them as much. The elasticity of high-quality accessions is probably about 1 [6]. If first-term pay is cut 15 percent, major additional savings will accrue.

8. CONCLUSION

To our knowledge, very little analysis has been performed on the payoff to on-the-job training after apprenticeship. That was the focus of our analysis. We demonstrated that such training significantly enhances performance in the Navy. For the most part, we measured the performance of maintenance personnel in terms of the condition of the equipment they maintain. Econometric techniques were used to estimate the productivity of these people in terms of their impact on their unit's ability to perform its mission. This is how military personnel should be evaluated.

It was impossible to take this approach for nonmaintenance personnel. For them we adopted a more subjective approach. The results of the two approaches were consistent. Further, by estimating the costs of personnel with different amounts of experience, from both a billet and an individual perspective, we showed that the Navy should buy more of it. This would allow readiness to be improved with no increase in costs. We suspect that this is true in other military organizations as well. The need for extreme youth and vigor is not what it once was in many military tasks. The fact that civilian employers use a far more senior work force to undertake tasks like many done in the Navy is, we suspect, not accidental.

9. REFERENCES

[1] Horowitz, Starley A., et al. CNA, Study 1090, "Crew Characteristics and Ship Condition, Maintenance Personnel Effectiveness Study (MPES)," March 1977

[2] Marcus, A.J. Center for Naval Analyses Professional Paper 363, "Personnel Substitution and Navy Aviation Readiness," October 1982

[3] Diewert, W.E. "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," Journal of Political Economy, Vol. 76, 1971

[4] Butler, Robert A. and Frankel, Oliver L. "The Billet Cost Model System" prepared under contract N00123-81-D-0841 for the Naval Personnel Research and Development Center (Department of the Navy, San Diego, CA 90822) by the Assessment Group, Santa Monica, CA 90401. Publication R-207, July 1983

[5] Balis, Ellen. Center for Naval Analyses Professional Paper 380, "Balancing Accession and Retention: Cost and Productivity Tradeoffs," March 1983

[6] Goldberg, L.E. CNA, Study 1068, "Enlisted Supply: Past, Present, and Future," September 1982

[7] Warner, J.T. and Goldberg, Matthew S. Center for Naval Analyses Professional Paper 337, "The Influence of Non-Pecuniary Factors on Labor Supply: The Case of Navy Enlisted Personnel," December 1981

[8] Quester, Aline and Marcus, A.J. CNA Memorandum 82-1525.10, "The Growth of Productivity in the First Term," October 1982

CNA PROFESSIONAL PAPERS[1]

PP 407[2]

Laird, Robbin F. *The French Strategic Dilemma*, 22 pp., Nov 1984

PP 415

Mizrahi, Maurice M. *Can Authoritative Studies Be Trusted?* 2 pp., Jun 1984

PP 416

Jondrow, James M., and Levy, Robert A. *The Displacement of Local Spending for Pollution Control by Federal Construction Grants*, 6 pp., Jun 1984 (Reprinted from *American Economic Review*, May 1984)

PP 418

Reslock, Patricia A. *The Care and Feeding of Magnetic Tapes*, 7 pp., Jul 1984

PP 422

Quester, Aline, and Marcus, Alan. *An Evaluation of The Effectiveness of Classroom and On the Job Training*, 35 pp., Dec 1984. (Presented at the NATO Defense Research Group Conference, Brussels, Jan 1985)

PP 423

Dismukes, N. Bradford, and Weiss, Kenneth G. *MARE MOSSO: The Mediterranean Theater*, 26 pp., Nov 1984. (Presented at the Seapower Conference, Washington, D.C., 26-27 November 1984)

PP 425

Horowitz, Stanely A., and Angier, Bruce N. *Costs and Benefits of Training and Experience*, 18 pp., Jan 1985. (Presented at the Symposium on Training Effectiveness, NATO Defense Research Group, Brussels, 7-9 January 1985)

PP 427

Cavalluzzo, Linda C. *OpTempo and Training Effectiveness*, 19 pp., Dec 1984. (Presented at the NATO Defense Research Group Conference, Brussels, Jan 1985).

1. CNA Professional Papers with an AD number may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151. Other papers are available from the Management Information Office, Center for Naval Analyses, 2000 North Beauregard Street, Alexandria, Virginia 22311. An index of selected publications is also available on request. The index includes a listing of profesional papers, with abstracts, issued from 1969 to December 1983).
2. Listings for Professional Papers issued prior to PP 407 can be found in *Index of Selected Publications (thrugh December 1983)*, March 1984.

END

FILMED

6-85

DTIC